January 1958

B.B.C. Research Department

CORRIGENDUM

Report No. T-063

Serial No. 1956/25

Dr. N.W. Lewis of the G.P.O. has drawn attention to an error in the above report.

The error in question relates to Figure 4 (page 7) for which the responses of vestigial-sideband systems were calculated by means of subtraction from unit-step responses of the same responses delayed by a time equivalent to ten picture elements for each system. Such a method may only be used for linear transmission networks and is not applicable to vestigial-sideband systems.

Thanks are due to Dr. Lewis for pointing out this error. The author wishes to point out that the error is in no way due to Mr. J.W. Head to whom the calculations required for Figure 4 were ascribed.

The correct version of Figure 4 is given herewith. It is to be noted that the conclusions drawn in the report are not altered by the change because they were not based upon this particular figure.

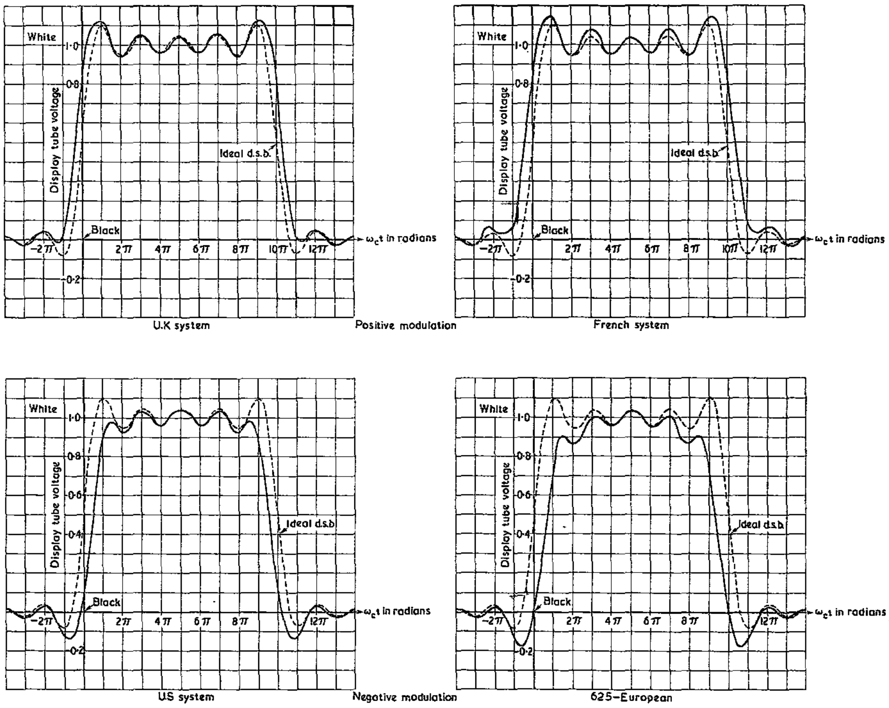

Fig. 4 - Normalized rectangular pulse responses (demodulated outputs).
The demodulated normalized display tube video voltage is given by

$$E'(t) = \frac{2}{r}\left\{ -\frac{1}{2}a + \sqrt{\left[\frac{1}{2}a + \frac{r}{2\pi}\left\{\mathrm{Si}\,\omega_c t - \mathrm{Si}\,\omega_c(t - 10\pi/\omega_c)\right\}\right]^2 + \frac{r^2}{4\pi^2}\left[\frac{\sin t\Delta\omega}{t\Delta\omega} - \frac{\sin \Delta\omega(t - 10\pi/\omega_c)}{\Delta\omega(t - 10\pi/\omega_c)} + \mathrm{Ci}\,\omega_c t - \mathrm{Ci}\,\omega_c(t - 10\pi/\omega_c) - \mathrm{Ci}\,t\Delta\omega + \mathrm{Ci}\,\Delta\omega(t - 10\pi/\omega_c)\right]^2}\right\}$$

RESEARCH DEPARTMENT

A COMPARISON OF FOUR TELEVISION STANDARDS

Report No. T-063

(1956/25)

W Proctor Wilson

R.D.A. Maurice, Ing.-Dr., A.M.I.E.E.

(W. Proctor Wilson)

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Report No. T-063

A COMPARISON OF FOUR TELEVISION STANDARDS

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August 1956

Report No. T-063

(1956/25)

A COMPARISON OF FOUR TELEVISION STANDARDS

SUMMARY

The resolutions of four C.C.I.R. standard television systems are compared, some account being taken of the effects of asymmetric sideband reception. The extent to which some of the distortions may be due to non-linearity of the phase-frequency characteristic is briefly mentioned.

1. INTRODUCTION.

Discussion occurs on many occasions as to the relative merits of the various television standards that have been adopted in different parts of the world. Some aspects of these television systems will be summarised below. It is not proposed here to make any suggestions as to possible improvements but merely to make technical comparisons. The systems considered are the U.K. 405-line, the French 819-line, the U.S. 525-line and the European 625-line standards as set out in "C.C.I.R. Documents of the VIIth Plenary Assembly, London 1953", Volume 1, Report No. 35, pp. 240 - 259.

The results and conclusions reached are obtained from a theoretical study of the unit-step, unit-impulse and rectangular-pulse responses, or responses to an abrupt transition from black to white, to a single white dot and to a vertical white bar of each television system having the characteristics shown in the above C.C.I.R. document, subject to the additional assumption that the video circuits prior to the transmitter consist of an ideal (uniform amplitude, uniform group delay) low-pass filter of cut-off frequency at least $\omega_c/2\pi$. The receiver characteristic is also assumed to have uniform group delay. It can be shewn that the departure from uniformity of group delay caused by a sufficient approximation to the standard shape of vestigial sideband receiver characteristic can be negligible.* Envelope demodulation has been assumed.

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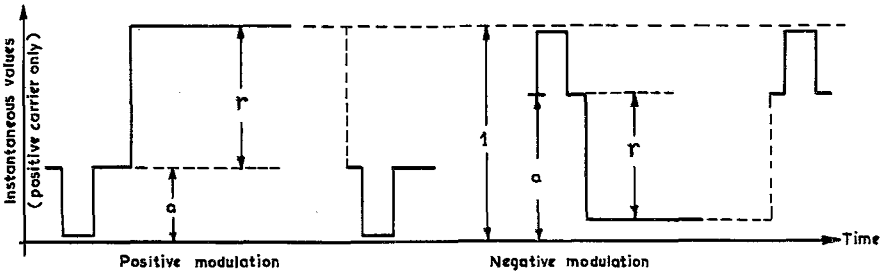
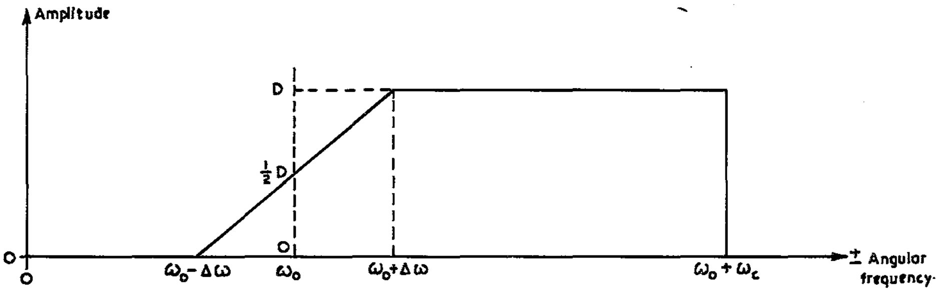
*See Appendix.

The parameters of the system which have been taken into account in the calculations from which the material in this paper has been obtained are as follows:



The transmitted waveform



The ideal receiver characteristic
(usually formed by the intermediate frequency circuits)

Fig. 1

the bandwidth on either side of the vision carrier for which the ideal receiver characteristic is non-uniform, the highest video frequency component transmitted without attenuation relative to components at low video frequencies, the polarity of the modulation, the magnitudes of the carrier wave for the two extreme positions of an abrupt transition from black to white transmitted without aperture distortion, the number of active lines, the active line duration and the channel allocation in megacycles per second. Table 1 summarises the values of these parameters.

TABLE 1

(See Fig. 1)

System	a	r	ω_c Mrad./s	$\lvert\Delta\omega\rvert$ Mrad./s	Number of active lines	Active line duration μ s	Channel allocation Mc/s
U.K.	0·3	0·7	$2\pi \times 3$	$2\pi \times 3/4$	377	81	5
French	0·25	0·75	$2\pi \times 10{\cdot}4$	$2\pi \times 2$	737	41	14
U.S.	0·75	-0·6	$2\pi \times 4$	$2\pi \times 3/4$	497	53	6
European (625-line)	0·75	-0·65	$2\pi \times 5$	$2\pi \times 3/4$	597	53	7

a = carrier amplitude during transmission of electrical black level.

r = difference between carrier amplitudes corresponding to transmission of peak-white and electrical black level.

ω_c = highest video angular frequency to which transmitter modulator will respond.

$2\Delta\omega$ = width in angular frequency of non-uniform portion of receiver amplitude/ response characteristic.

2. INTERPRETATION OF THE CALCULATIONS.

2.1. Unit-Step and Unit-Impulse Excitations.

Although the various systems have different magnitudes for the value of r (Table 1 and Fig. 1), the demodulated transitions have been normalised to a transition from zero voltage (current) to unit voltage. Figs. 2 and 3 shew these normalised transitions and two ideal cases assuming double sideband transmission and reception.

Figures for transition time, number of effective elements per complete picture and astigmatism are open to argument as various interpretations are possible. Therefore, all such figures have been normalised relatively to the U.K. system, although, of course, they could as easily be normalised to any of the other systems. To clarify the meaning of the figures for relative astigmatism, however, the absolute figures for the U.K. system are shewn in columns 7 of Tables 2 and 3. All the figures are based upon the actual transition times taken to climb from 0·1 to 0·9 in the unit-step case and from 0 through the maximum to 0 again for the unit-impulse case except in the European and U.S. examples, for which column 2 of Table 3 shews figures less than unity. For these two cases the ideal double sideband figures have been used, since the number of picture elements per line cannot exceed the ideal figure allowed by the video bandwidth.

TABLE 2

Unit-Step Transition

Column 1	2	3	4		5		6	7	8
System	Transition time normalised to ideal system and to video cut-off frequencies	Transition time normalised to U.K. system and to video cut-off frequencies	Overshoot %		Greatest overshoot % as excess over:		Excess resolution provided as % of that of U.K. system	Astigmatism relative to that of U.K. system	Resolution per Mc/s of channel allocation relative to that of U.K. system
			in blacks	in whites	ideal system	U.K. system			
Ideal double sideband	1	0·92	9	9	0	-2½	-	-	-
U.K.	1·09	1	½	11½	2½	0	0	1*	1
French	1·16	1·06	-	15	6	3½	227	1·2	1·17
U.S.	1·18	1·08	15½	-	6½	4	6	1·7	0·88
European (625-line)	1·40	1·28	19½	-	10½	8	34	1·9	0·96

*The actual value (normalised to 1 in the table) of the ratio of the length of a picture element to its height is 0·75 in this case.

TABLE 3

Unit-Impulse Transition

Column 1	2	3	4		5		6	7	8
System	Transition time normalised to ideal system and to video cut-off frequencies	Transition time normalised to U.K. system and to video cut-off frequencies	Overshoot %		Greatest overshoot % as excess over:		Excess resolution provided as % of that of U.K. system	Astigmatism relative to that of U.K. system	Resolution per Mc/s of channel allocation relative to that of U.K. system
			in blacks	in whites	ideal system	U.K. system			
Ideal double sideband	1	0·78	21	-	0	4	-	-	-
U.K.	1·29	1	17	-	-4	0	0	1*	1
French	1·35	1·05	15	-	-6	-2	228	1·17	1·17
U.S.	0·83	0·64	24	-	3	7	49	1·17	1·24
European (625-line)	0·79	0·61	24	-	3	7	119	1·13	1·55

*The actual value (normalised to 1 in the table) of the ratio of the length of a picture element to its height is 1·0 in this case.

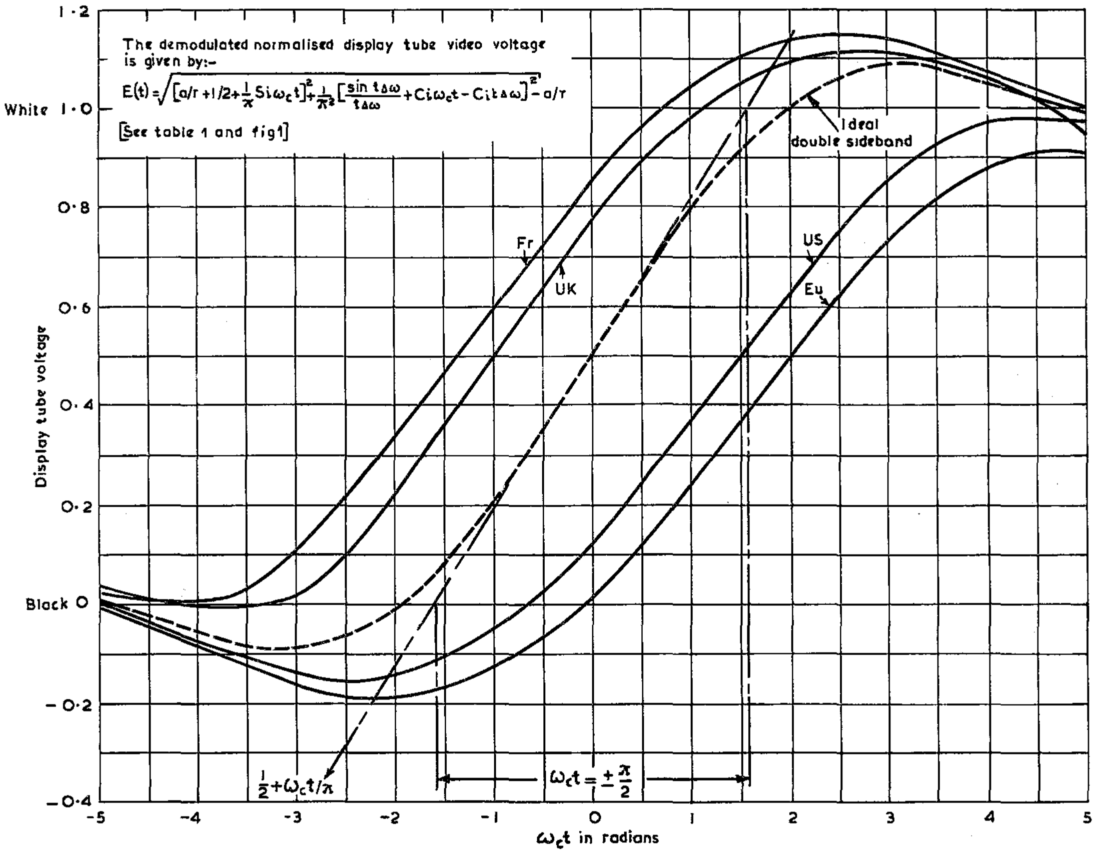


Fig. 2 - Normalised unit-step responses (demodulated outputs)

2.2. Rectangular Pulse Excitation.

Whilst Figs. 2 and 3 shew the unit-step and unit-impulse responses, it was considered that the response of each system to a rectangular pulse of ten picture-element duration would bring out more clearly the effect of modulation polarity coupled with asymmetric sideband reception.

Fig. 4* shews the responses to such an excitation. The ideal double side-band case is shewn dotted with each response. It should be remembered that the curves shewn in Figs. 2, 3 and 4 have all been calculated with the assumption that there is no phase distortion (uniform group delay) whatever in the entire transmission and reception.

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* The author is indebted to Mr. J.W. Head of this department for the calculations required for these graphs.

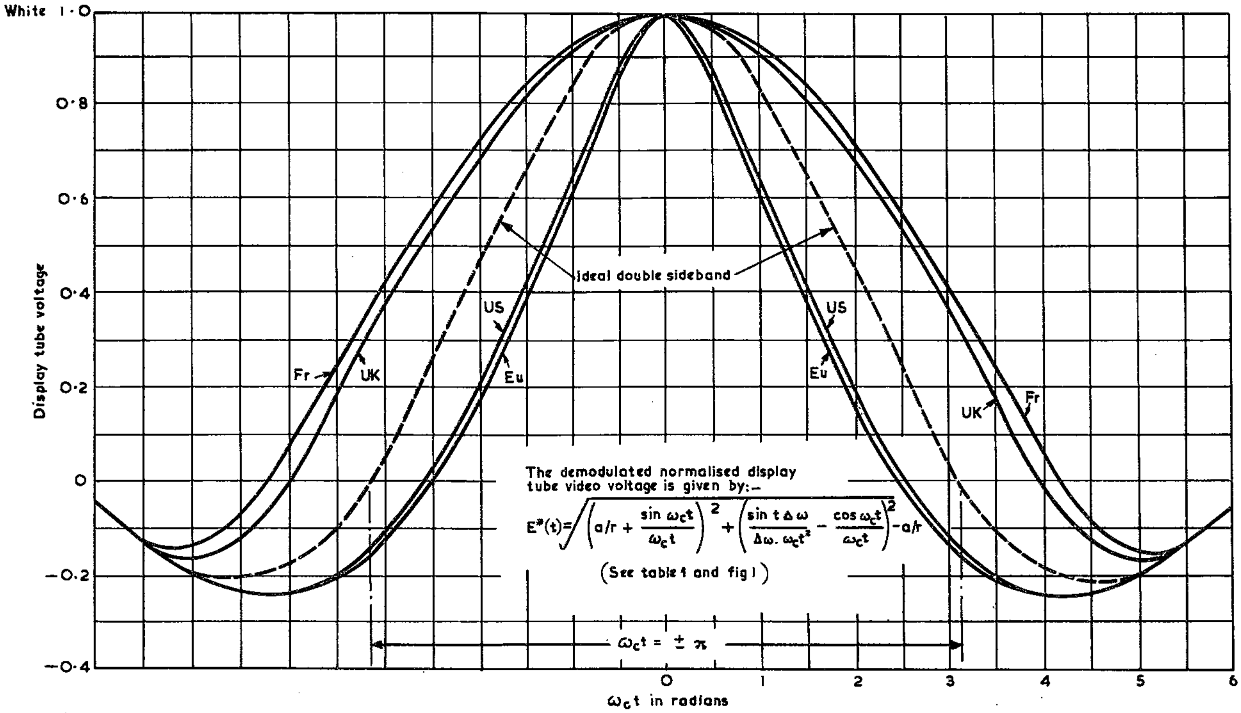

Fig. 3 - Normalised unit-impulse responses (demodulated outputs)

3. RESULTS AND CONCLUSIONS.

Tables 2 and 3, which are more or less self-explanatory, are obtained from the curves shewn in Figs. 2 and 3 in conjunction with the parameters given in Table 1.

It has been stated elsewhere * that the human eye characteristic shewing sensation units as a function of brightness approximates to a power law whose exponent does not differ greatly from the reciprocal of that of the gamma law of normal picture tubes.

For this reason the overshoot figures shewn in columns 4 and 5 of the tables may be taken as representative of the actual sensations of brightness which the viewer would suffer. Columns 6 shew the ratio of the total number of picture elements reproducible by each system to the figure for the U.K. system expressed as a percentage of the latter. Columns 7 shew the ratio of the astigmatism of each system to that of the U.K. system; thus if n is the ratio of the horizontal width of a picture element to its vertical height, then columns 7 show $n_{system}/n_{U.K.}$ Columns 8 shew which systems use their allotted radio frequency bands more or less efficiently than the U.K. Columns 2 shew that an asymmetric sideband system has a longer unit-step transition time (Table 2) than the ideal double sideband system, but that this is no longer true for unit-impulse transitions in systems using negative modulation (Table 3).

It would be tempting to take an average of the resolution figures shewn in

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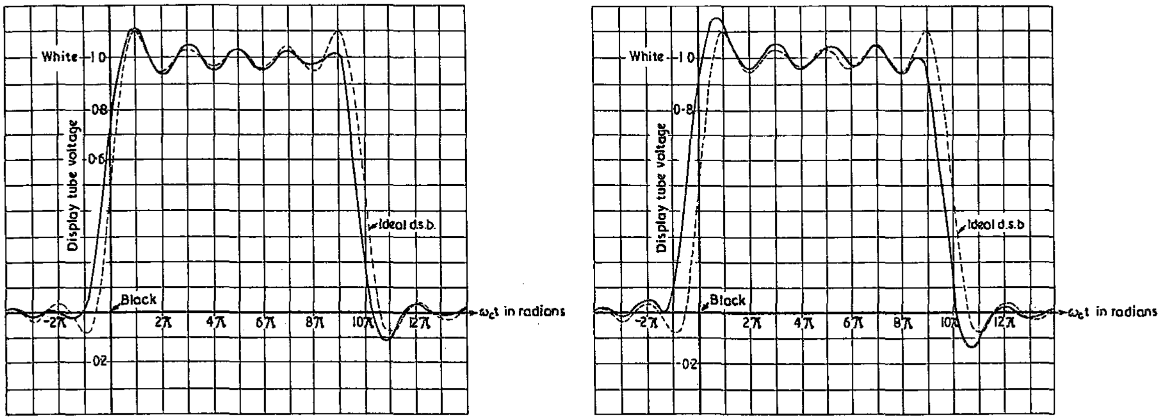
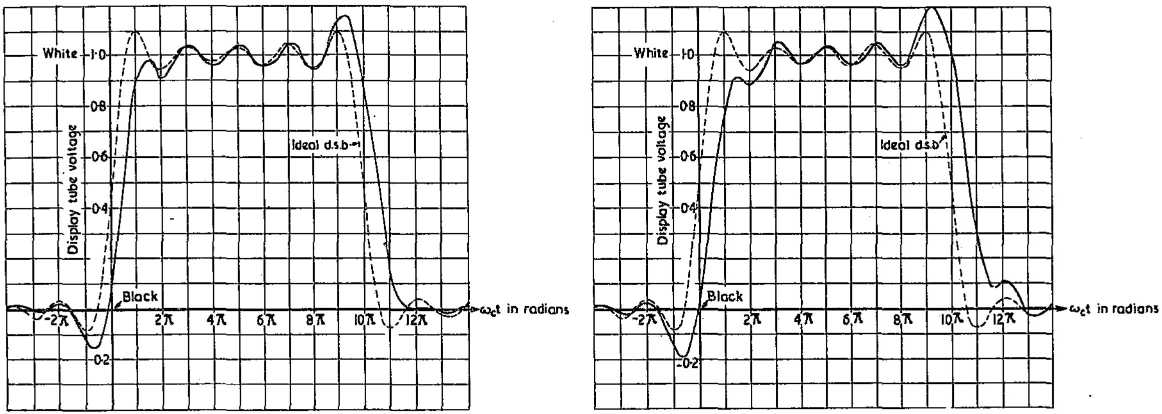
*B.B.C. Engineering Division Monograph No. 3, page 5.



UK system Positive modulation French system



US System Negative modulation 625-European

The demodulated normalised display tube video voltage is given by:- $E(t) - E(t - 10\pi/\omega_c)$
where $E(t)$ is given on fig.2

Fig. 4 - Normalised rectangular pulse responses (demodulated outputs)

columns 6 and also of channel efficiencies as shewn in columns 8, thereby combining the unit-step and unit-impulse results into overall averages; but the very fact that different results are obtained for different types of modulation function (unit step or unit impulse) shews that the non-linearity introduced by envelope detection of asymmetric sideband signals precludes such methods.

A further point of interest is the question of how much distortion is contributed by the non-uniformity of group delay over the frequency band encompassing the non-uniform portion of the modulus of the receiver transfer function situated close to the vision carrier. It is shewn in the Appendix that there exist circuits having satisfactory amplitude/frequency characteristics which do not give rise to serious phase distortion, and opinions differ as to whether or not practical receiver circuits come into the above category. Some light can be thrown on to this question by comparing Fig. 2 with Fig. 5 which is taken from Fig. 6 of the interesting article by

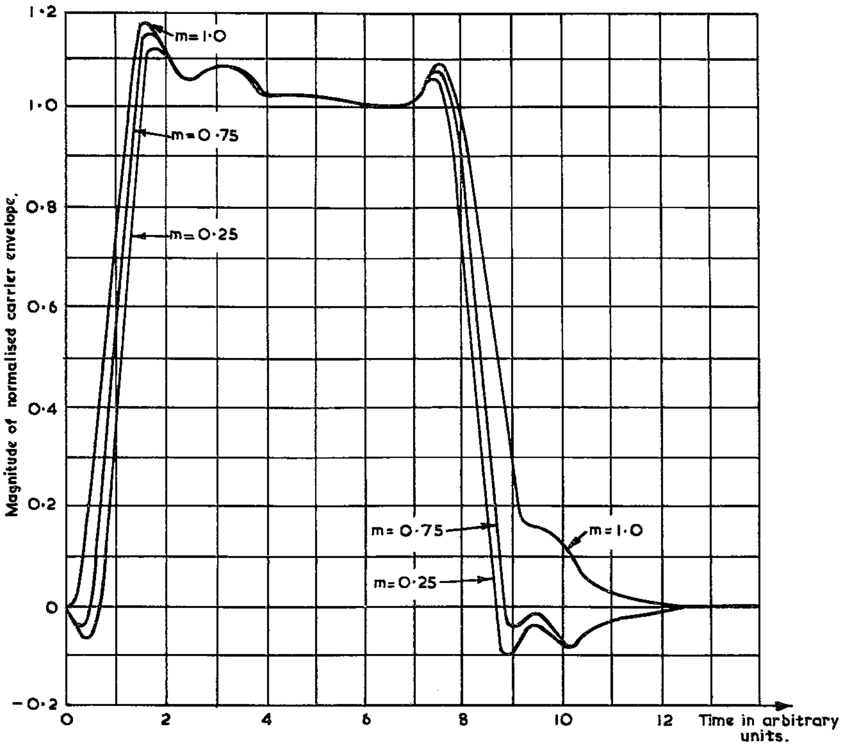


Fig. 5 - Response of a maximally flat staggered-triple tuned-bandpass coupled circuit to a broad rectangular pulse of carrier at the frequency of 1/2 response

Murakami and Sonnenfeldt in R.C.A. Review for December 1955 (Vol.XVI, No.4). In this figure, m is the modulation depth; that is, 1 - m is the magnitude of the vision carrier envelope during maximum inward excursions. The left-hand portion of the pulse corresponds with outward excursions of the carrier, whilst the right-hand portion is due to inward excursions. Now a black-to-white transition, Fig. 2, gives rise to an outward excursion for the U.K. and French systems, whereas the same transition in the U.S. and European systems produces an inward excursion; thus we shall first compare the left-hand side of Fig. 5 with the "Fr" and "UK" transitions in Fig. 2. The appropriate values of m are m(Fr) = 0·75 and m(UK) = 0·7. Now Fig. 5 refers to a bandpass coupled circuit possessing that amount of phase non-linearity which might be expected to be typical of television receiver circuits, whereas Fig. 2 results from a characteristic which is free from this. From Fig. 5 we see that the greater m becomes, the longer the transition time, and this trend is also discernible in Fig. 2. Furthermore, that the greater overshoot takes place at the end of the transition rather than at the beginning is shewn by both figures. Secondly, we compare the right-hand side of Fig. 5 with the "US" and "Eu" transitions in Fig. 2, only in this case we must remember that the bottom of Fig. 2 corresponds with the top of Fig. 5 and that m(US) = 0·8 and m(Eu) = 0·87. These higher modulation depths assist the comparison between the two figures. Note that the pre-shoot is now greater than the overshoot and, significantly, for high m $(0{\cdot}75 < m \rightarrow 1)$ the transition is not actually accomplished for a relatively considerable time: the well-known "smear" effect occurs.

The above comparisons are not made easier by the presence of ideal filter "cut-off rings" in Fig. 2 and practical filter "cut-off rings" in Fig. 5; nevertheless it is thought that there exists some evidence here for exonerating a well-designed receiver from transient distortions caused by phase non-linearity over the non-uniform portion of the amplitude/frequency characteristic situated around the vision carrier frequency.

The only conclusion which can be made from the meagre results obtained is that theoretical comparisons of television systems must be thoroughly supported by very complete field trials before any one system can be said to be superior to any other.

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Murakami, T. and Sonnenfeldt, R.W., "Transient Response of Detectors in Symmetric and Asymmetric Sideband Systems", R.C.A. Review, Vol. XVI, No. 4, December 1955.

APPENDIX

It might be argued, in spite of the comparisons made above between Figs. 2 and 5, that the comparisons made between the four television systems dealt with in the foregoing text could be falsified by the presence of non-uniformity of group delay over the region of receiver amplitude/frequency characteristic including the linear portion close to the vision carrier — it being well known that a change of gain or modulus of a transfer function is accompanied by a change of group delay.

This question has been examined for one example of transfer function (the Butterworth type) which may perhaps be regarded as a very convenient theoretical "building block" for the examination of the asymptotic characteristics of low-pass, high-pass and band-pass filters.

The problem was to find a modulus or amplitude/frequency response-function which would adequately simulate the ideal asymmetric sideband reception characteristic shown in Fig. 1 and then to calculate what the group delay of such a network would be if it were of the minimum-phase type. If the resulting group delay had departed seriously from uniform shape it would then have been necessary to calculate again the unit-step and unit-impulse responses taking account of the phase shifts

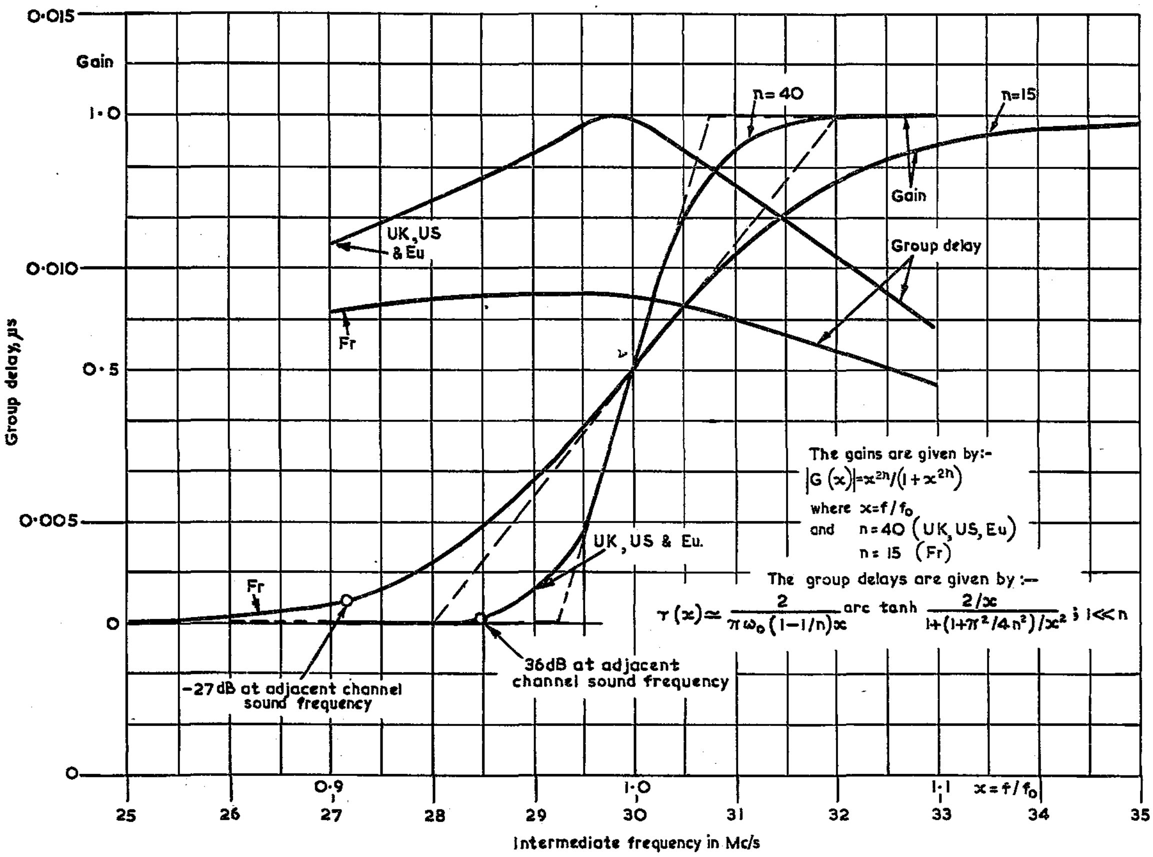

Fig. 6 - Amplitude & group delay responses of an idealised network

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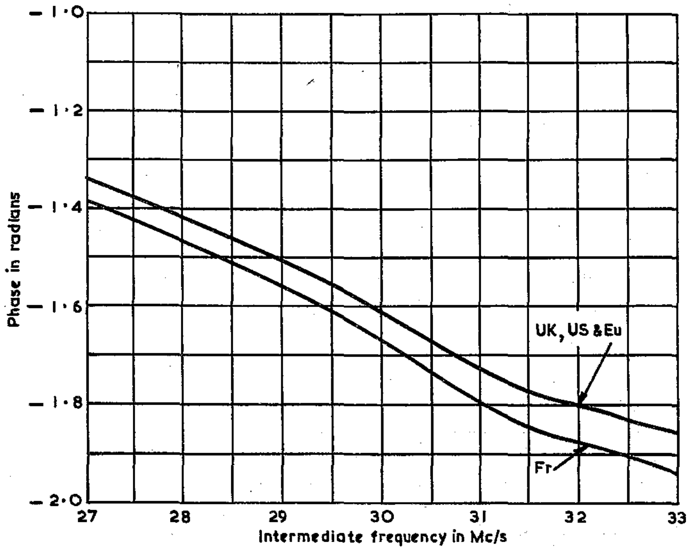
Page 11, note to Fig. 7:- $B = \frac{2}{\pi}\int_{o}^{x}\frac{1}{t}\,\mathrm{arc\ tanh}\,t\,dt$ *

should read $B(x) = \frac{2}{\pi}\int_{o}^{x}\frac{1}{t}\,\mathrm{arc\ tanh}\,t\,dt$ *

resulting from the variations of group delay. Such a calculation would have been laborious, but it was found that the group delay non-uniformities resulting from amplitude/frequency characteristics of satisfactory shape were quite negligible, provided that receiver demodulators were of the non-coherent or envelope variety. Synchronous demodulation is never used for obtaining the luminance component of black-and-white or colour television signals, so that we may now rest assured that the comparisons made between the four television systems in the main text are valid within the restrictions and assumptions given therein. Fig. 6 shews two amplitude/frequency characteristics: one suitable for receiving a French transmission and the other suitable for receiving U.S., U.K. and European transmissions. The corresponding group delay curves are shewn on the same figure. Phenomena relating to



The integrals with respect to ω of the group delay curves in fig6

Fig. 7 - Phase shift in an idealised network

The phase is given by:

$$\phi(x) \simeq -\frac{2}{\pi(1-1/n)}\left\{\pi B(x) - \frac{2(K^2-1)}{\sqrt{K^4+6K^2+25}}\left[\frac{1}{\sqrt{\alpha}}\arctan\frac{x}{\sqrt{\alpha}} - \frac{1}{\sqrt{\beta}}\arctan\frac{x}{\sqrt{\beta}}\right]\right\}$$

where $K^2 = \dfrac{1}{1-\pi^2/4n^2}$

$\alpha = \tfrac{1}{2}(K^2+5-\sqrt{K^4+6K^2+25})$

$\beta = \tfrac{1}{2}(K^2+5+\sqrt{K^4+6K^2+25})$

$x = f/f_0 \simeq 1\,, \quad B = \dfrac{2}{\pi}\displaystyle\int_0^x \frac{1}{t}\,\mathrm{arc\,tanh}\,t\,dt$ *

*Corrington, M.S. "Table of the integral $\dfrac{2}{\pi}\displaystyle\int_0^x \frac{\tanh^{-1} t}{t}\,dt$ ", R.C.A. Review, Vol. VII, No. 3, Sept. 1946.

attenuation of sidebands corresponding to high video-frequency components are not considered here. The two phase/frequency curves which represent the integrals of the group delay functions are shewn in Fig. 7.* Figs. 6 and 7 refer to a high-pass Butterworth characteristic of modulus $x^{2n}/(1+x^{2n})$ where $x = f/f_0$, in which the appropriate attenuation slope is obtained by using a suitable value of n. The relative smallness of group delay may be appreciated for many practical values of attenuation slope by examination of Fig. 8** which shews the change of normalised group delay, $\omega_0\ [\tau_{max}(x) - \tau\ (o)]$, as a function of attenuation slope in decibels per octave.

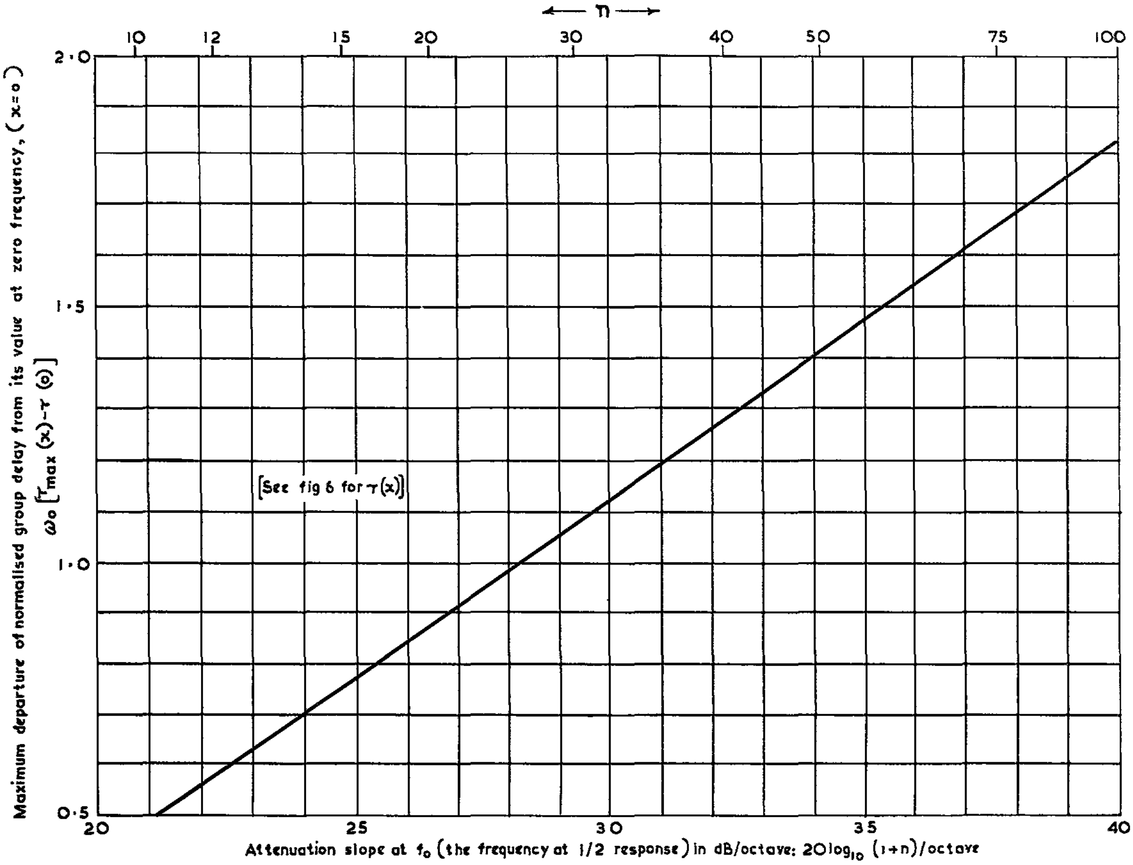


Fig. 8 - The effect of rate of change of attenuation at vision carrier frequency $x = f/f_0 = 1$, upon the departure from uniformity of group delay

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*The author is indebted to Mr. J.W. Head for his co-operation in effecting the integrations.

**The author is indebted to Mr. S.J. Lent of this department for this figure.

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